PRV

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BERGLUNDS PATENTBYRÅ AB

ASPEBRÅTEN
590 55 STUREFORS

Sökande: **Nordic Sensor Technologies AB, Teknikringen 8, 583 30 Linköping SE.**

Ombud: **Berglunds Patentbyrå AB. Ref: P9720.**

Benämning: **Elektronisk tunga.**

Skriftligt svar skall ha kommit in till PRV senast 1999-01-07 c/64

Om svar inte kommit in inom angiven tid, avskrivs ansökningen (jfr 15 § patentlagen).

U T L Å T A N D E

Uppfinningen

Ansökan avser ett förfarande för kvalitativ analys av en vätska. Förfarandet går till så att elektriska pulser av varierande spänning skickas till elektroder som står i kontakt med vätskan. Pulserna genererar ström- och/eller spänningstransienter vilka sedan registreras och utvärderas. Ansökan innefattar även en anordning kallad "elektronisk tunga" vilken arbetar enligt ovan beskrivna metod.

Anförda dokument

Vid granskningen har följande dokument bedömts som mest relevanta:

GB 2 127 977 A
US 4 321 322 A1
US 4 897 162 A1
EP 0 557 642

Forts.

U P P L Y S N I N G A R

Patentkrav får inte ändras så att det kommer att innehålla något som inte framgår av grundhandlingarna. Ändras patentkrav så att nya bestämningar tillkommer, skall samtidigt anges var motsvarighet finns i grundhandlingarna. Ändrade handlingar skall inges i två exemplar.

Motivering och bedömning

Patentkrav 1, 8:

GB 2 127 977 (se t.ex patentkraven och sidan 1 rad 81-83) redogör för en mätmetod med elektrod vilken står i kontakt med vätskan som ska analyseras, där den resulterande strömmen mäts direkt efter pulsgenereringen. Den beskrivna mätmetoden får anses vara ekvivalent med den i krav 1 beskrivna mätningen av transienter. Att utvärdera resultatet av mätningen med hjälp av olika i och för sig kända ("multivariate") metoder får anses närliggande för fackmannen.

Förfarandet och anordningen enligt patentkrav 1 och 8 saknar uppfinningshöjdoch är därmed inte patenterbara.

Patentkrav 3-7, 9:

Beträffande krav 3 och 9 så beskriver US 4 897 162 hur över-lagrade elektriska spänningspulser varieras under förfarandet och hur dessa inducerar en ström som mäts, se kolumn 4 rad 8-9 samt kolumn 6 rad 3-18. Skriften redogör även för användandet av en pulsgenerator, se kolumn 10 rad 51. Beträffande användning av överlagrade spänningspulser se även EP 0 557 642, t.ex kolumn 3 rad 3-32.

Beträffande krav 4-5 så beskrivs i US 4 321 322 en mätmetod där elektriska spänningsspulser tillförs elektroder som står i kon-takt med den undersökta substansen och där resulterande ström mäts och utvärderas med hjälp av ett mikrodatorsystem, se kolumn 3 rad 24-29 och kolumn 4 rad 47-50. Elektroderna kan varieras med avseende på både material och utföringsformer, se kolumn 6 rad 65-kolumn 7 rad 43.

Med kännedom om ovan nämnda skrifter och känd teknik anses det närliggande för fackmannen att komma fram till en lösning enligt kraven 3-5, 9.

Inte heller patentkrav 6-7 kan anses annat än närliggande för fackmannen med hänsyn till dokumenten ovan.

Metoden och anordningen enligt patentkraven 3-7, 9 saknar uppfinningshöjd och är därmed inte patenterbara.

Övriga brister

Krav 2 är oklart och bör förtydligas. Det framgår inte tydligt hur och när storheterna ström, spänning, konduktivitet, energi, respektive effekt genereras respektive mäts i förhållande till varandra. Det är inte heller helt klart vad som avses med "the other entity".

På svenska språket avfattad beskrivning, patentkrav och samman-drag har inte ingivits i föreskrivna två exemplar. De på svenska avfattade handlingarna ska, om de inte utgörs av vederbörligen styrkta översättningar, vara försedda med intyg om att deras innehåll har motsvarighet i de utländska handlingarna.

Forts.

De ingivna ritningarna är inte utförda i föreskrivet skick (engelsk text).

Ingivna ritningsexemplar är inte utförda med svarta linjer på vitt, matt ritpapper.

Överlåtelsehandling saknas.

I tjänsten

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Intyg
Certificate

Härmed intygas att bifogade kopior överensstämmer med de handlingar som ursprungligen ingivits till Patent- och registreringsverket i nedannämnda ansökan.

This is to certify that the annexed is a true copy of the documents as originally filed with the Patent- and Registration Office in connection with the following patent application.

(71) Sökande Nordic Sensor Technologies AB, Linköping SE
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BERGLUNDS PATENTBYRÅ AB

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1997 -09- 07

Huvudfaxen Kassan

Sökande: **Nordic Sensor Technologies 1A**

Titel: **AN ELECTRONIC TONGUE**

Uppfinnare: **Fredrik Winquist & Peter Wide**

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There is a growing interest in recent years for the concept of electronic noses. An electronic nose consist of an array of gas sensors with different selectivity patterns, a signal collecting unit and pattern recognition software applied to a computer. The principle is based on the fact that a large number of different compounds contributes to define a measured odor, the chemical sensor array of the electronic nose then provides a pattern output that represents a synthesis of all the components. The pattern output is given by the selectivities of the various sensors.The very essence of the electronic nose is that the combination of several specificity classes has a very large information content.

Electronic noses have already been established for qualitative analysis in various fields of the analytical chemistry, and there are already commercial instruments on the market. Due to the similarities with the human olfaction, these systems have been cited as "electronic noses"..Recently, similar concepts, but for analysis in liquids, have been described. These systems are in similar ways related to the tasting sense, thus, for these concepts the terms "electronic tongue" or "taste sensor" have been coined. An electronic tongue was thus described based on a number of chalcogenid glass electrodes, combined with a pattern recognition routine for measurement of metal ions in river water (Ref 1). A more complex sensor composition consisting of glass electrodes and PVC membranes for tasting of beverages has also been described (Ref 3).

Similar concepts, denoted "taste sensors", have also been described. Thus, a LAPS (light addressable potentiometric sensor) with artificial lipid membranes as ion selective material has been described (Ref 4), as well as taste systems, based on a fibreoptical sensor array using potential sensitive dyes (Ref 5) or on a surface photovoltage technique applied to Langmuir-Blodgett films (Ref 6).

A taste sensor based on lipid/polymer membranes on a multichannel electrode has also been developed (Ref 2). This concept has been commercialized as Taste Sensing System SA401, by Anritsu Corp., Japan.

A common feature for these electronic tongues or taste sensors described, that the sensing principle is based solely on potentiometry, the charging of a membrane being measured.

This will limit the area of detectable compounds to ions or other charged species.

Thus, these known taste sensors are not sufficiently discriminating to allow for instance quality monitoring in e.g. food processes. The variation in the response to different parameters is not sufficient and despite the use of pattern recognition methods as known from the electronic nose technique the resulting patterns are not separable with sufficient precision.

Furthermore, potentiometric measurements per se are sensitive to electronic noise, putting high demands to the electronics and measurement set-up.

In view of the above mentioned problems encountered with known taste sensors or electronic tongues the object of the invention is to improve the pattern response to variations in tested substances. This object is achieved by a generation of transients by applying electrical pulses to electrodes in contact with the substance to be investigated, the transients are registered and evaluated by multivariate methods as measurement principle. Normally in voltammetry for instance, the very first moments when electricity is applied to the electrode is not considered at all and one normally waits for the more steady and thus more easily predictable conditions that follow. For the invention which may be employed to give an electronic tongue, it has, however, been found that the initial signal transient response obtained when electricity is applied will vary significantly when the tested substances vary and thus the pattern will also vary with different voltages, pulse wave forms and frequencies.

Contrary to known measuring the initial transients at different voltages are recorded instead of the later stabilized conditions. The great variation obtained is however of great advantage in the invention (for instance an electronic) tongue were the important thing is to achieve as different patterns as possible for small changes in test substance. Whether the changes in signal response are predictable in a calculable sense of the word or not are however without interest provided that a given change result in the same recognition pattern change every time, which it does. The normal disadvantage can thus be considered as an advantage at the invention.

The excitation waveform consist of successive pulses of different voltages, pulse wave forms and/or frequencies, between which a base potential can be applied or superimposed.

The response signal, for instance the current transient at voltammetry may be measured during the forward step of a square pulse, after return to the initial condition, or both.

The pulse generated may have various origins, the principle may be based on measurements on current, voltage, effect, energy or conductivity, due to onset of pulses of voltage, current or combinations thereof.

The instantaneous faradic current at the electrode is related to surface concentrations and charge transfer rate constants, and exponentially to the difference of the electrode potential from the start value to the final potential. Various parts of the curve thus reflects amount and type of either charged or electroactive species in a complicated and superimposed way.

The current - time curve shape (A) due to the onset of a voltage pulse is schematically shown in figure 1.

At least four regions can be distinguished:

a/ Incoming charged and/or redox active species starts to build up a Helmholtz layer. This region is dominated by type and amount of charged species.

b/ Mixed region of incoming charged (dominating part)and/or redox active species

c/ As in b above, but the reaction of redox active species is the dominating part of the current.

d/ Equilibrium is achieved, and the current in solely based on reduction/oxidation of redoxactive species.

Curve B (transient at the end of the pulse) is reversed from that of A. A different shape is, however, obtained due to the different compounds near the electrode surface.

If the voltage pulses are superimposed by a variable signal, for example on a voltage ramp, the corresponding current-time curve will be as shown in figure 2. Similar interpretations

as in the previous case can be made.

Since the pulses may be short the influence of the measuring on the tested substance may become negligible, also the shape and size of the electrodes may be chosen more freely. For instance the electrodes may have a larger size than normally increasing the signal response. Also the short pulses allow rapid testing or monitoring as well as the collection of responses from a great number of pulses with different voltages.

In one configuration of the invention two types of pulse voltammetry may be used, based on large amplitude pulse voltammetry and small amplitude pulse voltammetry, in the following abbreviated as LAPV and SAPV, respectively.

In LAPV, the electrode is held at a base potential, at which negligible electrode reactions occur. After a fixed waiting period, the potential is stepped to a final potential. A current will then flow to the electrode, initially sharp when a Helmholz double layer of charged species is formed and electroactive compounds next to the electrode surface are oxidized or reduced. The current will then decay exponentially as the double layer capacitance is charged and electroactive compounds are consumed, until the diffusion limited faradic current remains. The size and shape of the transient response reflects amount and diffusion coefficients of both electroactive and charged compounds in the solution. When the electrode potential is stepped back to its start value, similar but opposite reactions occur.

In the SAPV, a slow continuous DC scan is applied to the electrode on to which small amplitude voltage pulses are superimposed. This will cause a change in the concentration profile of the electroactive species at the surface. Since only small changes in the electrode potential are considered, this will result in small perturbations in the surface concentration from its original value prior to the application of the small amplitude excitation.

When using pulsed voltammetry, information can also be obtained from AC current versus frequency curves at various potentials. The potential may vary around zero or be superimposed on an other arbitrary statical or dynamical potential curve.

In continuous voltammetry, the current depends of the diffusion rate of electroactive species to the working electrode. If the stirring rate in the measurement cell is changed, also the electrode current is changed. One way to overcome this is to use microelectrodes, due to favourable diffusion profiles, an other way is to use pulse voltammetry, conductometry, effect or energy measurements.

Pulse voltammetry also enables the use of macroelectrodes that can be cleaned by rather harsh methods, which often is necessary to get clean electrode surfaces. Microelectrode are much more fragile.

The invention also deals with the aspect of influencing the measured solution at one position and to make measurement at an other position, so close that measurement will be affected. This means that compounds generated at one electrode are detected (together with other compounds in the solution) by the other electrode. Since both electrodes may be operated at different potentials and pulse conditions, a very large but also very complicated information concerning the measured solution may be obtained increasing the possible variations in the transients and thus provide a big base for the pattern recognition. In case of streaming or flowing liquids being tested influencing electrodes or materials as for instance catalytic materials can be placed upstream of some electrodes to change the composition before it is tested by other electrodes.

Further developments of the invention are apparent from the subclaims and the following description of experimental tests of the invented method. The description refer to the appended drawings showing:

Figure 1	A schematic current-time transient due to the on/off set on a voltage pulse;
Figure 2	A schematic current-time transient due to the on/off set on a voltage pulse, superimposed on a ramped voltage onset;
Figure 3	Schematics of the experimental set-up;

Figure 4 A typical recording from LAPV, also showing the position of measurement points. Pulse time and time between pulses are also indicated;

Figure 5 A typical recording from SAPV, also showing the position of measurement points. Pulse time and time between pulses are also indicated.

Figure 6 Score plot for the experimental series. The samples were investigated after each other as shown in Table 2.

The basic principle behind the electronic tongue is to combine unspecific and overlapping signal transients with pattern recognition routines. Within this invention, various pulsed voltammetric techniques can be applied to generate information when combined with a multivariate method, such as principal component analysis,partial least square fits, artificial neural nets, fuzzy logic, genetic algorithms or similar statistical or "artificial intelligent" methods. In the invention, also various curve fitting methods may be used to characterize the pulse responses obtained.

The invented method can normally be divided into four steps:

- Use of pulse voltammetry (or other electrical measurement methods) to obtain information (transient curves) ;
- Use of different electrode materials or modified electrodes or pulse voltage etc to obtain different chemical reactions varying the transients;
- Use of curve fitting methods to extract or sample information from the obtained set of transients;
- Use of various multivariate signal processing methods to interpret this thereby gained information.

Prototype variations of the invention

A prototype of an electronic tongue has been designed, based on the combination of pulse voltammetry using two types of working electrodes and principal component analysis (PCA). This electronic tongue was able to classify various samples, such as fruit juices,

still drinks and milk. It was also possible to follow aging processes of milk and orange juice when stored at room temperature.

Chemicals:
The samples in the experiment consisted of 6 different brands of orange juices.

Equipment:
The experiments were carried out in a standard three electrode configuration, containing a double working electrode, an auxiliary electrode consisting of a 20 * 50 mm^2 plate of stainless steel, and a Ag/AgCl (KCl 3M) as reference electrode. The double working electrode consisted of one wire of platinum and the other of gold, both with a length of 5 mm and a diameter of 1 mm. The electrode configuration was placed in a 150 ml measurement cell, also containing a magnetic stirrer kept at room temperature. Current transient responses were measured by a potentiostat connected to a PC via an A/D - D/A converter. The PC was used for onset of pulses and measurement of current transient responses and to store data. Via two relays, the PC was also used to shift type of working electrode (gold or platinum). A schematic of the experimental set-up is shown in Figure 3.

All voltage referred to in the following are versus the Ag/AgCl electrode.

In general for LAPV, a measurement sequence starts by applying a potential during 470 msec., then the voltage is set again to 0 volt during the same time, whereafter the cycle starts all over. By each cycle, the applied potential is decreased by a given value. Measurement values after onset of pulse at 100 msec and 430msec., respectively, are collected, as well as the measurement value obtained 100 msec. after offset of the pulse, making altogether 3 data points for each cycle. A typical recording is shown in Figure 4, also showing the position of the measuring points. The pulse time, L1, and time between pulses, L2, are also indicated in the figure.

For the SAPV, the potential is scanned from a start value to a final value, and small voltage pulses are superimposed. Each cycle starts by decreasing the potential with a step value during 180 msec., followed by increasing the potential with a superimposed value

during 180 msec. Measuring points are collected 100 msec after onset of the step potential and 100 msec after onset of the superimposed potential. The difference between these two measurement points is also taken as a data point, making altogether 3 data points collected for each cycle. A typical recording is shown in Figure 5, also showing the position of the measuring points. The pulse time, L1, and time between pulses, L2, are also shown in the figure.

Data analysis:

Principal component analysis on the data obtained was performed with a commercial software.

Results obtained of the prototype:

An experimental series were performed, the samples investigated are shown in Table 1. A PCA plot for the whole series of samples is shown in Figure 6. The samples were normalized by dividing by mean in each column. A clear separation between the various samples can be seen.

In the above experiment the concept of an electronic tongue based on the invention demonstrates its capabilities in being able to classify various fruit drinks and milk, and also to be able to follow some aging processes. This opens up future possible applications in e.g. the food industry.

A further development of the concept is also to use other metals as working electrodes, such as palladium, rhodium and iridium or in some other way change the electrode properties by e.g. surface modifications, use of alloys, etc.... Furthermore, electrodes and setups may be used were the measuring electrodes or special electrodes influence the tested liquid. The invention is not limited to liquid matter since solid matters can be tasted by wetting and then testing.

Table 1

Sample number	Sample type	Sample number	Sample type	Sample number	Sample type
1	Ph1	16	M4	31	OC4
2	Ph2	17	M5	32	OA3
3	Ph3	18	M6	33	OA4
4	Ph4	19	OE1	34	OB3
5	Ph5	20	OE2	35	OB4
6	OA1	21	OE3	36	SA1
7	OA2	22	OF1	37	SA2
8	OB1	23	OF2	38	SA3
9	OB2	24	OF3	39	SB1
10	OC1	25	OD1	40	SB2
11	OC2	26	OD2	41	SB3
12	OC3	27	OD3		
13	M1	28	A1		
14	M2	29	A2		
15	M3	30	A3		

Table 1
The experimental series carried out consecutively. The samples are:
Phosphate buffer at pH 7.0: Ph
Orange juice: OA, OB, OC, OD, OE, OF
Milk: M
Apple juice: A
Orange still drink: SA, SB

References

[1]C. Di Natale, F. Davide, A. D'Amico, A. Legin, A. Rudinitskaya, B.L. Selezenev and Y. Vlasov, "Applications of an electronic tongue to the environmental control", Technical digest of Eurosensors X, Leuven, Belgium (1996) 1345-1348.

[2]K. Toko, "Taste sensor with global selectivity", Materials Science and Engineering C4 (1996) 69-82.

[3]A. Legin, A. Rudinitskaya, Y. Vlasov, C. Di Natale, F. Davide, A. D'Amico, "Tasting of beverages using an electronic tongue based on potentiometric sensor array", Technical digest of Eurosensors X, Leuven, Belgium (1996) 427-430.

[4]Y. Sasaki, Y. Kanai, H. Ushida and T. Katsube, "Higly sensitive taste sensor with a new differential LAPS method", Sensors and Actuators B 24-25 (1995) 819-822.

[5]S. Yamakawa and A. Yamaguchi, "Optical responses of potential-sensitive dye/PMMA coatings to taste solutions", Sensors and Materials 7, 4 (1995) 271-280.

[6]Y. Kanai, M. Shimizu, H. Uchida, H. Nakahara, C.G. Zhou, H. Maekawa and T. Katsube, "Integrated taste sensor using surface photovoltage technique", Sensors and Actuators B 20 (1994) 175-179.

CLAIMS

1. Measuring method, **characterized in** a generation of transients by applying electrical pulses to electrodes in contact with the substance to be investigated, the transients are registered and evaluated by multivariate methods.

2. Method according to claim 1, **characterized in** for each pulse is either current, voltage, energy, conductivity or effect controlled and that the other entity is registered for the case of current or voltage or conductivity being controlled, whereas in the case of the effect being controlled either the current or the voltage may be registered.

3. Method according to any of the previous claims, **characterized in** subsequent electric pulses being varied for instance to their current and/or voltage values, to their shape, or in the relation between pulse and pause between the pulses, or the frequency, alternatively the pulses may be superimposed on a rising or falling current or voltage curve.

4. Method according to any of the previous claims, **characterized in** the use of a number of different measure electrodes of for instance different materials or coated by different materials, or modified in different ways, or placed so in relation to each other that the electrodes influence each other or that their measuring influence each others result.

5. Method according to any of the previous claims, **characterized in** the measuring principle being voltammetric, potentiometric or conductometric, and of one, two or three electrode type.

6. Method according to claims 4 or 5, **characterized in** a cyclic subsequent switching of a common current or voltage generator and/or a registration device between different measuring electrodes resulting in ample time between the pulses to each electrode to allow the influence of the previous pulse on the liquid to have ceased before next pulse arrives to the same electrode.

7. Method according to any of the previous claims, **characterized in** the transients being

treated with suitable shape enhancing or developing techniques, as for instance derivation, integration, proportionality, etc. before the evaluation by means of multivariate recognition methods or other similar classification methods.

8. Electronic tongue, **characterized in** comprising a pulse generator coupled to electrodes for the contact with the substance that is to be investigated, a registration device for registering the transients obtained at the applying of the pulses and a computer for evaluation of the transients with multivariate pattern recognition methods.

9. Electronic tongue, **characterized in** the computer being coupled also to control the pulses to their size shape or frequency etc. or to interact between the pulse generated and the measured response.

ABSTRACT

Electronic tasting carried out by feeding short electrical pulses to electrodes and a registration of current and/or voltage transients for these pulses [at distinct times]. For each test sequence a number of pulses with different voltage are used. The obtained signals are then recognized or compared by a pattern recognition program in a computer for instance to see if a liquid substance as beer or milk lies within set quality limits.

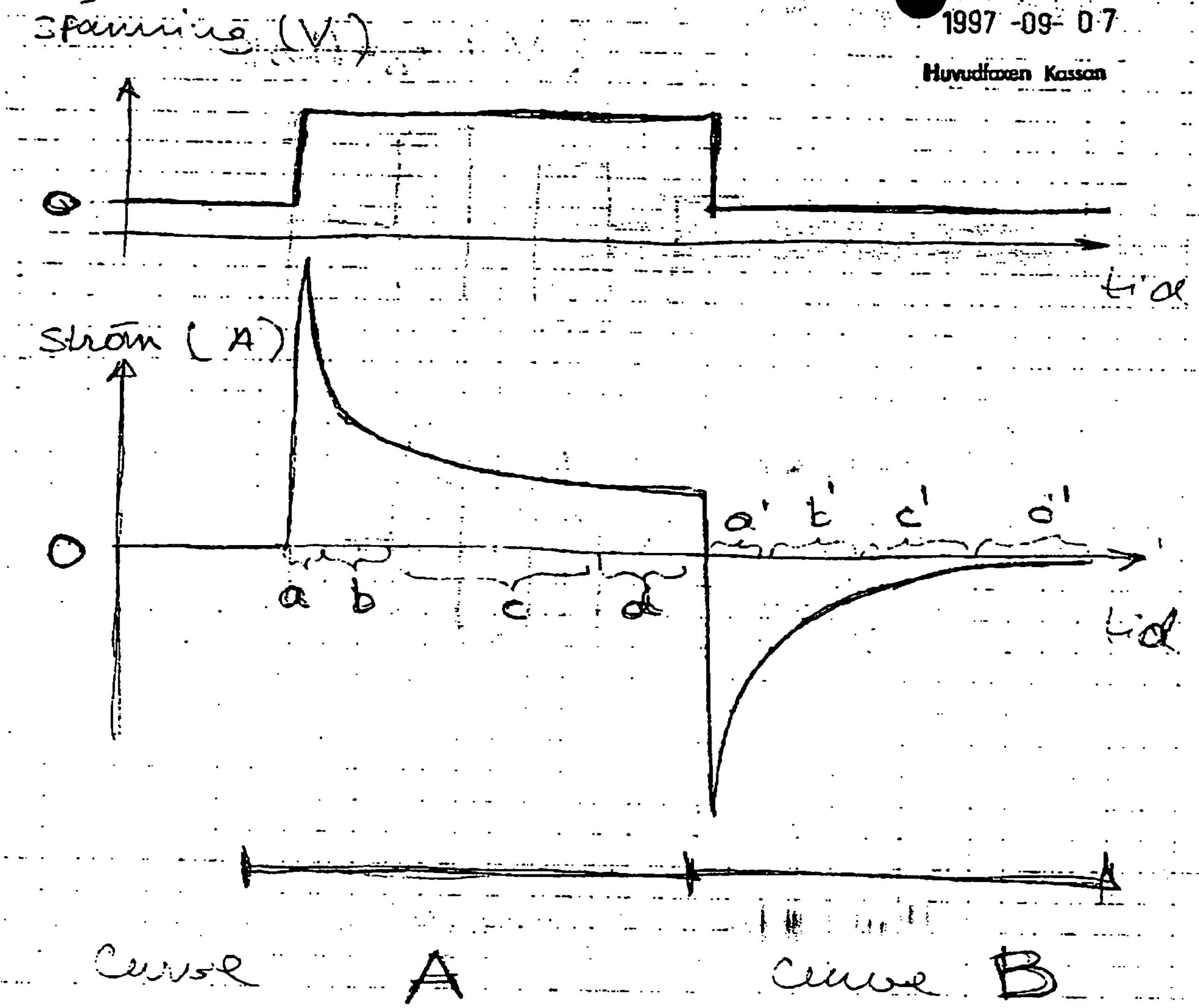


Figure 1

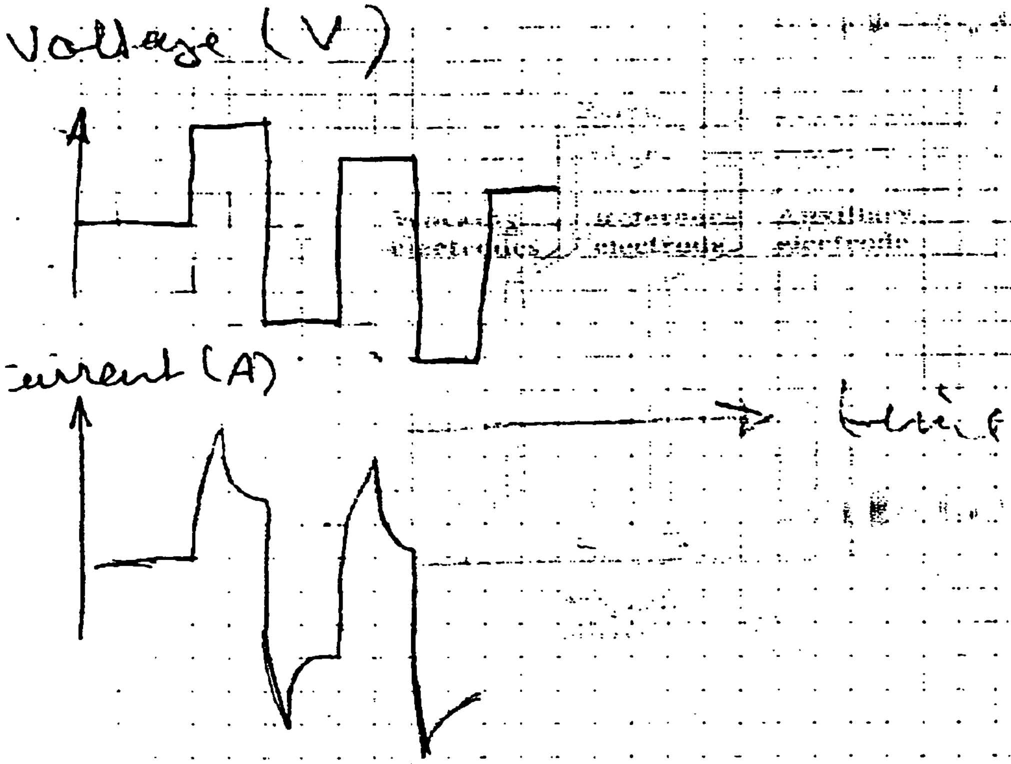
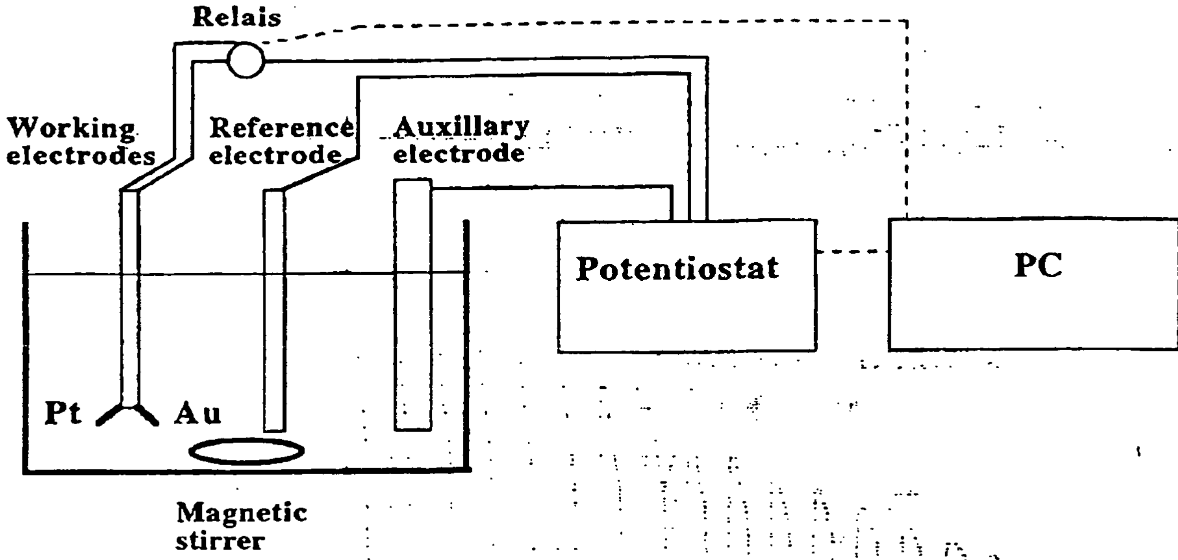


Figure 2



Measurement cell

FIGURE 3

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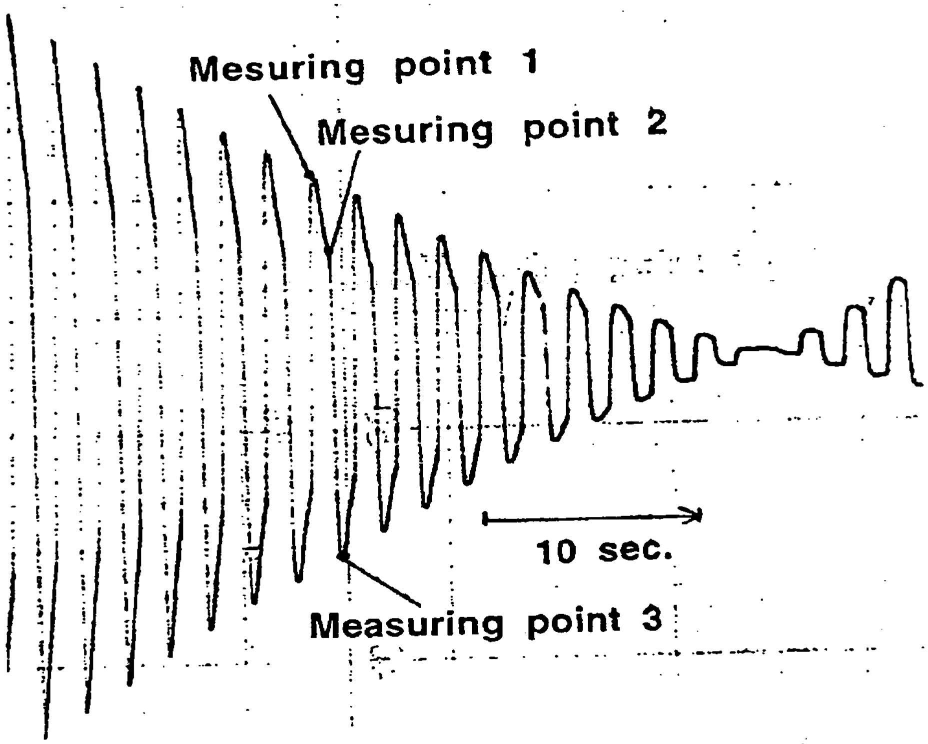

FIGURE 4

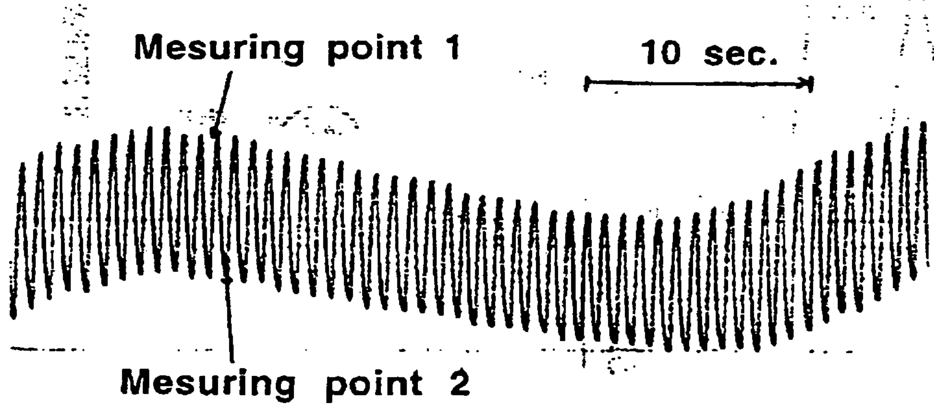

FIGURE 5

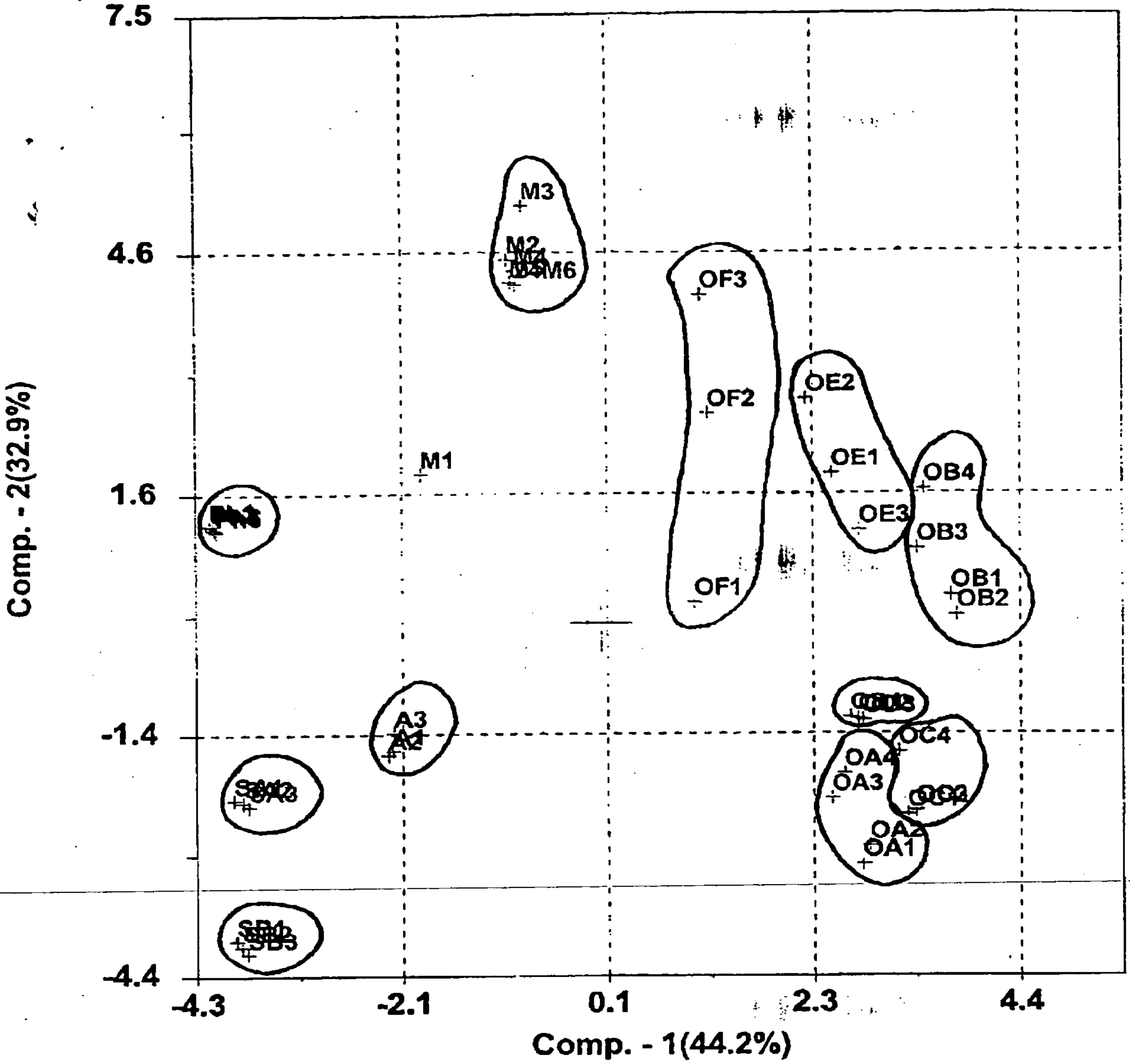
7.5
4.6
1.6
-1.4
-4.4
-4.3
-2.1
0.1
2.3
4.4
Comp. - 2(32.9%)
Comp. - 1(44.2%)
M3
M2
M6
M1
OF3
OF2
OF1
OE2
OE1
OE3
OB4
OB3
OB1
OB2
A3
OC4
OA4
OA3
OA2
OA1

FIGURE # 6